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Notes on Sugarcane Cultivation in Java.

BY

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The development of the sugar industry in Java furnishes a most striking example of the successful application of science to agriculture. The organization of scientific experiment in connection with sugarcane cultivation and sugar manufacture was first undertaken in 1885 through the establishment of an experiment station for Middle Java at Semarang. In the following year a station for West Java was established at Kagok which was later transferred to Pekalongan while, in 1887, one was established at Pasoeroean near Soerabaya for the benefit of the sugarcane growers of East Java (see map, Fig. 1).

The stations which owed their inception to the severe economic crisis through which the sugar industry was passing at the time and to the appearance of the very serious sugarcane disease, "Sereh", were originally financed by the three separate sugarcane growers' associations of the regions mentioned. It is out of place here to trace in detail the development of these stations and the amalgamations which have gradually followed. It is sufficient to note that, with the establishment, in 1907, of a central organization (Vereeniging het Proefstation voor de Java Suikerindustrie) for the control of all experimental work on sugarcane and sugar manufacture, the

work of the various stations was co-ordinated and gradually concentrated on the East Java station so that, by 1924, the West and Middle Java stations had been closed and their work transferred to Pasoeroean with a subsidiary station at Cheribon in Semarang Province for the special study of sugarcane diseases. Even this work was being transferred to Pasoeroean at the time of my visit and I was given to understand that, hereafter, the work at Cheribon would be confined largely to demonstration.

The Experiment Station for East Java (Proefstation Oost-Java) at Pasoeroean is undoubtedly the largest, the most fully equipped and the best organized station for a tropical crop in any part of the world. It is financed through a levy which, at present, amounts to 5 guilders per bouw (approximately Rs. 3 per acre) on all land cultivated with cane (including ditches and roads) by the 179 factories which belong to the Union. The present yearly income is over 1,400,000 guilders (approximately Rs. 15,50,000) and this is, to a certain extent, assured as the contribution is fixed for a period of three years.

The Station is divided into three sections, an agricultural section, a technological section and an engineering section, each with its own director. The directors are respectively Dr. V. J. Koningsberger, Dr. J. Honig and Professor von Pritzelwitz van der Horst. While each director has complete control over the experimental and demonstration work of his particular section, they together form a board for the administrative control of the station. Professor von Pritzelwitz van der Horst is the present chairman of the board.

My attention was directed almost entirely to a study of the work of the agricultural section and its effect upon sugarcane cultivation. However, I took the opportunity afforded by a week's stay in Pasoeroean to interview Professor von Pritzelwitz van der Horst and Dr. Honig and through the latter was brought into touch with the proprietors of the one large jaggory factory in Java which will be referred to in some detail later in this report.

Before attempting a description of the work at Pasoeroean and in the field by the staff of the Sugarcane Experiment Station it seems necessary to refer briefly to the special conditions which govern sugarcane cultivation in Java.

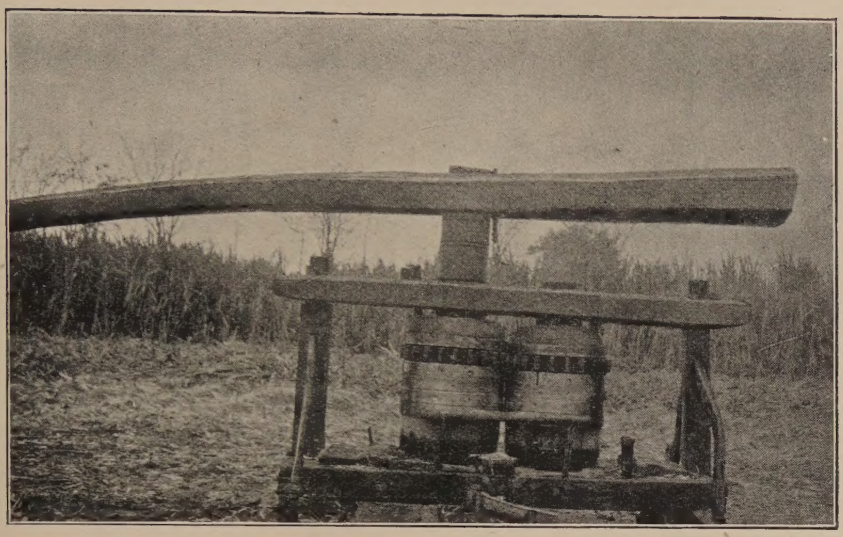


FIG. 2.—Wooden Sugarcane Mill—East Java. The two wooden rollers are shod with steel bands.

FIG. 3.—Field prepared for sugarcane planting.

FIG. 4.—Field of young cane showing drainage-irrigation channel. East Java Station.

FIG. 5.—Cane about two months old on the East Java Station in Reynoso furrows.

In the first place a word may be said about the so-called native cultivation of sugarcane. The average area under cane grown by the Javanese is about 39,000 acres or approximately the present cane area in Mysore. While this cultivation has undoubtedly benefited through its proximity to the large sugar estates in that the higher yielding varieties introduced on the latter have spread over to the native cultivation, still the production is low and the methods of sugarcane milling and jaggory manufacture are even cruder than those generally practised in India. The average production of cane to the acre is about 20 tons giving a return of 190 maunds of jaggory (1 maund=28 lbs.). As an example may be mentioned the fact that sugarcane mills consisting of two wooden rollers are still generally used for extracting juice. One of these is shown in Figure 2. While I have, many years ago, seen wooden mills somewhat similar to these stored away in the villages in inaccessible parts of Mysore, I doubt if a wooden mill has been used for the regular extraction of sugarcane juice in this State at any time during the past twenty-five years. The Department of Agriculture in the Dutch East Indies are now taking steps to popularize iron mills similar to those universally in use here. I was informed that they have also experimented with small power installations for the making of jaggory for the native cultivators, but that these have not been very successful.

The apparatus commonly used for boiling juice by the natives of East Java consists of a series of four or five small pans arranged over a common furnace the highest being nearest the furnace mouth. The juice is dipped from one pan to another in the course of evaporation. Rather ingenious cylinders made of woven bamboo are dropped on to these shallow pans during boiling to prevent the juice boiling over the sides. This furnace is hardly more efficient than the furnaces commonly used in this State while the jaggory manufactured is, on the whole, of no better quality.

If we turn to the cultivation on Estates, the contrast is most striking and one cannot but be impressed with the great care that is taken in all the operations and the scientific supervision that is exercised over them. The average production of sugarcane per acre on the whole area under factory management, consisting of about 473,000 acres, was, in 1928, 52.8 tons which represents a production of 6.3 tons of sugar. These figures give the returns for the year 1928.

There has been an increase since then. Figures of sugar returns and rendement (out-turn of sugar on sugarcane) prior to 1930 are given on the basis of muscovado sugar. Figures for 1930 are given on the basis of plantation white. On the more recently used basis, the figure yields of sugar would be 95% of 6.3 tons or 5.98 tons of sugar per acre.

Many factors have contributed to this remarkable result. Leaving for the moment out of account those factors which rest on the careful application of experimental results, there are certain natural ones which must not be lost sight of. In the first place the soils used for sugarcane are obviously very fertile. All of them are of recent volcanic origin and although they vary from a heavy clay, such as is found in the Sidoardjo delta lying between Pasoeroean and Soerabaya, to a rather light sandy loam sometimes mixed with gravel, as can be seen in some parts of the Malang plateau and as is still more common in the Besoeki Province at the extreme eastern end of the Island, all are decidedly more fertile than most of our sugarcane areas. This fertility is moreover being continually supplemented through the silt carried in the irrigation water. In Mysore, practically all our irrigation water for sugarcane is, at present, derived from storage tanks, where most of the silt is deposited while in Java irrigation is almost invariably from inundation canals which allow for the maximum carriage of silt on to the fields. The result is that many, if not most, of the soils on which sugarcane is grown react profitably only to the addition of nitrogenous fertilizers and even here the average optimum dose is considerably lower than it is in most parts of India. Reference will be made to this later.

If we turn to the question of climate, we find that, although climatically Java is better suited to the growth of sugarcane than Mysore, the most extensive as well as some of the most productive areas of cane are found in the driest regions of the island where the rainfall is not particularly copious and is hardly better distributed than it is in many parts of this State.

The accompanying table shows the distribution of factories according to the districts into which the sugarcane area of the island is divided for demonstration purposes, with the total area in acres in each district. These districts do not exactly correspond to the administrative districts or Residencies.

	District.	Factories.	Area of cane in acres.
1.	Besoeki	11	31,933
2.	Pasoeroean	27	66,554
3.	Soerabaya	35	71,074
4.	Kediri	20	63,096
5.	Madioen	7	23,618
6.	Soerakarta	16	46,895
7.	Djokjakarta	17	41,605
8.	Kedoe	2	11,678
9.	Banjoemas	5	17,110
10.	Semarang	11	27,019
11.	Pekalongan	17	43,938
12.	Cheribon	11	29,563
	TOTAL ..	179 factories.	474,083 acres.

An examination of Fig. 1 will show that the four districts given first in the table are at the eastern end of the island where the driest conditions prevail. These districts contain over half the factories in Java and almost half the total area under sugarcane. The map also gives the various zones of the island which have approximately the same number of rainy days during the four driest months of the year. It may be said that sugarcane cultivation is chiefly confined to areas having between no and twenty rainy days during these four months. An exception is the comparatively small area in the Banjoemas and Pekalongan Districts where the rainfall is distinctly heavier and more equably distributed. From the above it must be obvious that irrigation must play an important rôle in the growing of sugarcane in Java. Practically all the irrigation canals are, as stated, inundation canals and, although these give a much more abundant and equable supply of water in the dry season than do similar canals in India, instances are not infrequent where water is an important limiting factor in production. This has been particularly the case during the past three or four years when the rainfall has been distinctly below the average. I saw sugarcane fields which were said to have had no irrigation for from three to four months and which showed distinctly the effects of drought. As will be shown later in this report, one of the most important contributions of science to the development of sugarcane production

in Java has been the production of a cane variety which, through its efficient root system and vigorous growth, is able to withstand the unfavourable conditions of soil moisture which result from long periods of drought.

Another very important factor working in the same direction is the water-holding capacity of the soils upon which sugarcane is grown. While these are varied, they are in general very much more retentive of moisture than are our soils in Mysore. Especially is this the case with the deltaic soils in the Soerabaya Residency, one of the most important sugarcane areas in Java, but during my whole tour, which covered practically all of the sugarcane areas of the East Java, I saw practically no soils so lacking in moisture-retaining power as many of the soils upon which sugarcane is grown in this State.

As is well known, the methods followed in the cultivation of sugarcane in Java are conditioned largely by the system of land tenure. On the sawahs or irrigated lands which represent the bulk of the Java sugarcane area, cane is grown in a three-year rotation immediately following paddy on land which is leased from the native holders. The leases usually run for 21 years though in the two principalities (Vorstenlanden) Soerakarta and Djokjakarta they run, at times, for 25 years. The rotation system precludes the possibility of growing a ratoon crop and, in fact, the native cultivators are prohibited from growing a ratoon crop on the land which has been handed back to them after the sugarcane has been harvested. The object of this prohibition lies in the necessity for the production of food crops to feed the very dense population of Java. The rotation usually practised is soy beans or maize, paddy, sugarcane. On the comparatively restricted areas of dry land (tegallans) which are found chiefly in the Kediri and Probolingo areas this rotation is not practised and a ratoon crop of cane can be grown.

The rentals paid by the sugar companies for the land are fairly high. According to information I was able to obtain, these vary from 30 to 60 guilders per hectare (Rs. 13 to Rs. 23 per acre) for tegallans and from 125 to 200 guilders per hectare (Rs. 56 to Rs. 90 per acre) for sawahs. It is claimed by the sugar companies that these rentals give to the owners of the land considerably higher returns than they could obtain by cultivating the land themselves. The rent to be paid by the sugar companies for land is not solely a matter of agreement. A minimum

rate of rental is fixed by officers of Government after enquiry on the spot.

The method of preparing the land for planting and of laying out the sugarcane fields including the drainage and irrigation ditches, which is commonly known as the Reynoso system, has been frequently described. It must not be forgotten that this system has been devised especially to meet the peculiar soil and cultural conditions obtaining in Java. It is also associated with the fact that there is an abundant supply of cheap labour in Java.

The fact that sugarcane follows paddy and that the former is rarely harvested more than six weeks before the beginning of the cane planting season (April) makes the rapid drying and preparation of the land a necessity. A drainage ditch has first to be dug around each field, to give an outlet for the water to be drained from the paddy fields. This is followed by the digging of parallel drainage ditches across the field, at distances varying with the character of the soil but commonly thirty feet apart. These allow for the rapid draining of the fields. As soon as the land is dry enough for hand digging, the planting furrows are then dug usually from twelve to eighteen inches deep and about twelve inches wide, the soil being piled up on to the ridges between the furrows. The width between the planting furrows from centre to centre varies but is usually about three and a half feet. Fig. 3 shows a field prepared ready for planting. Figs. 4–6 show young cane planted in Reynoso furrows on the Pasoeroean Experiment Station. As will be indicated later the optimum distance between rows and between the setts in the row varies according to the character of the soil and cane variety and is a question which is being carefully investigated on many estates.

The method of preliminary cultivation described above allows heavy and water retentive land to be prepared for planting much earlier than it could be by ordinary methods of ploughing. However, mechanical cultivation implements have been designed with which the cultivation of even the heavy deltaic soils can be done as effectively as by hand digging. There are two considerations which have prevented these implements coming generally into use. In the first place, while the ploughing and the preparation of planting furrows can be done rapidly and very efficiently, the digging of the

cross drains has still to be done by hand, and this will, obviously, be a more difficult and expensive task when the soil from the ditch has to be spread on the already prepared ridges than it is where these drainage ditches can be dug at the beginning. In the second place, while the use of mechanical means of cultivation saves hand labour the sugar estates cannot afford to let the labour go, for it is required in abundance for subsequent operations. The danger of labour being drawn off to other estates at the commencement of the season is a real one and must be guarded against. Hence, it would probably be advisable to utilize hand labour in preliminary cultivation, even if it were somewhat dearer than cultivation by mechanical means. It is interesting to note, therefore, that, while scarcity of labour after the war due to various causes, including political ones, led quite a considerable number of estates to experiment with mechanical methods of cultivation, the last four or five years have shown a sharp swing back to manual cultivation, so that in 1929 not one per cent of the total area under cane in Java was cultivated by mechanical means. This has not been at the sacrifice of early preparation of the soil, a matter of great importance. As a matter of fact, owing to a more adequate supply of labour, there has been a steady increase in the percentage of area planted early in season. This is shown very strikingly in the following table taken from Demandt, De Stand der mechanische Grondbewerking bij de Java Suikerrietcultuur tot het Oogstjaar 1929, Med. No. 16, Jaarg 1929, Archief voor de Suikerindustrie.

Percentage planted up to the end of each of the five main cane planting months :—

	April.	May.	June.	July.	August.
1920 ..	1	8	29	59	85
1925 ..	3	13	44	78	97
1929 ..	9	37	74	96	100

According to Demandt (*loc. cit.*) the cost figures for preparing land for cane planting by mechanical means as worked out in 1929 on the Assembagoes Estate, Besoeki Residency, were almost exactly Rs. 20 per acre. This included the cost of manual labour required for digging drainage and irrigation ditches. This is very considerably less than the average figures given to me for preparing fields by hand labour which was approximately Rs. 31 per acre. The

figures are, however, hardly comparable as the soil of the Assembagoes Estate is comparatively light and is particularly suited to mechanical cultivation.

The work of the Sugar Experiment Station from an agricultural standpoint, which formed the special subject of study, can be divided into two main parts :—1. Research work in the laboratories and on the experimental plots of the station itself, and 2. Field experiment and extension work on the sugar estates. This latter is carried on under the supervision of an extension section consisting of two inspectors and fifteen field officers (Groepsadviseurs) each of whom has about twelve estates under him. Many of the estates employ in addition their own field staff for conducting experiments.

The number and variety of these field experiments are very extensive, while the care with which they are carried out is remarkable. No experiment which does not involve ten repetitions is now taken into account by the station in compiling and studying results. During the year 1929, nearly 2,300 of these field tests were carried out. Of these over 1,500 had to do with manuring, while the remainder were concerned mainly with various methods of cultivation and planting and with the control of pests and diseases.

Of the manurial experiments, 1,146 were concerned with nitrogenous manuring. Of these 1,054 had to do with fixing the optimal dose of ammonium sulphate, 2 with replacement of ammonium sulphate by groundnut cake, 4 with its replacement by calcium cyanamide, and 168 with green manuring.

The average optimum dose of ammonium sulphate which stood at approximately 3.5 cwt. per acre during the years 1923–1927 has, in the past three years, risen to 4 cwt. per acre. This has been due very largely to the replacement of the older cane varieties by POJ 2878 which, in 1929, occupied over 80% of the total area and which was the only variety with which these experiments were carried out. It should be emphasized that the larger yields of sugar per acre which have, in Java, followed the introduction of POJ 2878, have been due to several factors of which the increase in the dose of nitrogenous manures is an important one. Another is the general increase in early planting which has been referred to above. A more efficient plant and more favourable conditions of growth following a better

planting season have made possible the economic utilization of considerably larger quantities of nitrogen as plant food. This is a striking illustration of an important point which I have emphasized for many years, *viz.*, that efforts towards the production of higher yielding varieties of crops must be accompanied by improvements in cultivation and manuring if we are to reap anything like the full benefit from their introduction. The average dose of ammonium sulphate applied to sugarcane fields in Java in 1928 was almost exactly 4 cwt. per acre which shows how closely practice follows experiment.

As regards the question of green manuring for sugarcane the conditions existing in Java do not usually allow for the growing of green manure crops before the cane nor for growing such crops on other land and then using them on the cane fields. The Dutch sugar planters are thus compelled largely to grow the green manure crop between the rows of cane. Under these conditions green manures have proved of no value.

As regards replacement of ammonium sulphate by groundnut cake and calcium cyanamide the number of experiments carried out have been too few to warrant definite conclusions. The use of groundnut cake to replace partially ammonium sulphate did not give favourable results, while those with calcium cyanamide were more promising. It will be remembered that groundnut cake was, at one time, one of the most generally used nitrogenous manures for cane in Java. It has now been almost entirely replaced by ammonium sulphate.

Turning to the question of phosphatic manures, the manure generally used is concentrated superphosphate (dubbelphosphaat). There is no such general need for phosphoric acid on the sugarcane soils of Java as there is for nitrogen. It was formerly believed that there was a definite phosphate limit in these soils below which cane would respond profitably to phosphatic manures but above which it would not. The experimental work of recent years has shown this to be erroneous and it has been established that the only way to ascertain whether cane will react to phosphatic manuring on a particular soil is by carrying out field experiments on that soil. Dr. C. van Dillewyn in his report on manurial trials for 1929 (Samenvatting van de Resultaten der Bemestings proeven van Oogst-Jaar, 1929, Archief voor de Suikerindustrie, 1930) states as follows :— "On the one hand POJ 2878 has given, on phosphate poor soils, in

30% of the cases no results from phosphatic manures ; on the other hand this variety has shown, on phosphate rich soils, a favourable reaction to phosphatic manuring." From the results tabulated by van Dillewyn it is seen that, where the addition of phosphoric acid has been advantageous about 2 cwt. of concentrated superphosphate per acre has, in the majority of the experiments, given the most favourable results. The average application in 1928 was roughly 1.7 cwt. of concentrated superphosphate per acre.

The experiments on the use of lime and potash manures were too few and too scattered to give any definite information. According to van Dillewyn there are, however, indications that POJ 2878 will respond to both of these manures.

As regards the use of cattle manure, it may be said that its value is recognized but that, as in India, the application is limited by the supply available. The amount applied per acre in 1928 if spread over the whole area under cane would have given little more than one-half ton per acre (one cart-load).

If we turn to questions other than those on manuring which have engaged the attention of Java sugarcane growers from an experimental standpoint they have been mainly those to do with factors connected with planting such as planting depth, planting time, distance between rows, distance between setts in rows, and source of seed. These together account for 616 experiments out of the 704 carried out on problems other than manurial ones during the year 1929. These are, of course, the very experiments which would become most necessary in connection with the introduction of a new variety such as POJ 2878. While it is out of the question to attempt to apply the results of experiments conducted in Java to our conditions, it may interest readers to have these results summarized.

In depth of planting experiments, the planting depth varied from 3 to 14 inches. Deep planting gave, in general, the best results especially on heavier soils. As to planting time, it may be noted that the planting season normally extends from April to August. In general, the results showed that the earlier plantings have given the best results. Thus, of 59 tests in which April is the earliest month of planting, 38 or 64 per cent gave April as the optimal month for planting, 17½ or 30 per cent, June and only 3½ or 6 per cent, July.

Also of 67 tests in which May was the earliest planting month, 44 or 66 per cent gave May as the optimal month, 18½ or 28 per cent, June and only 4½ or 6 per cent July.

In the case of row spacing experiments the majority of tests gave a distance of three and a half feet between the rows as the optimum, while in the case of tests on planting distance in the row the planting of one sett every one and a half to two feet in the row gave the highest returns. As the setts used commonly contain two eyebuds and are about 8 inches to one foot in length, this would mean a space of ½ to 1 foot between setts.

A very interesting series of observations have been made on the relation between the number of stalks and the production of sugarcane and sugar per unit area. The results obtained during the past three years with POJ 2878 show that the out-turn of both sugarcane and sugar has increased with the number of stalks up to the highest yet observed which would seem to indicate that as far as this variety is concerned the maximum had not yet been reached. The narrowing of distance between rows has led to a more regular increase in stalks per acre than a narrowing of distance between the setts in the row. As was to be expected an increase in number of stalks per unit area resulted in a decrease in the weight per stalk. Contrary to previous opinion, an increase in the number of stalks did not lead to more lodging of the cane. We have been carrying on in Mysore for a number of years, experiments on planting distances and while our experiments have been much fewer and less elaborate than those in Java, the results have been very similar.

If we turn to the production of cane and sugar per acre in Java the most recent figures (those for 1929) gave as the highest production on any estate in Java 1610 quintals of sugarcane and 220 quintals of sugar per hectare which corresponds in round figures to 64 tons of cane and 8.8 tons of sugar per acre. The estate which gave this very high return is a comparatively small one with an area of 1,540 acres under cane. The lowest average yield registered in any estate in Java was very slightly over half this amount. As already stated the average production for the year 1928 over all estates was 52.8 tons of cane and 6.3 tons of sugar per acre. This is an average calculated on approximately 374,000 acres of cane. The complete figures for 1929, which were not available to me, will, I believe, show

an increase over this average largely owing to the fact that the area under POJ 2878 has steadily increased during the past two years so that now this variety occupies about 98 per cent of the total area under cane in Java.

Yields of 53 tons of cane to the acre are not unknown in Mysore but we have a long way to go before we shall be able to show this as an average production over the whole of our sugarcane area.

Figures of cost of production obtained on a hurried tour of inspection, such as mine, must be accepted with very great reserve and I offer them with some diffidence. However, they may prove of some interest. The main charges connected with the cultivation of sugarcane are as follows :—

1. *Rent of land.*—For paddy land (sawahs), which forms the great bulk of the sugarcane area, this varies between 125 and 200 guilders per hectare. This is equivalent to Rs. 55 to Rs. 90 per acre. I was informed that the rental went up, at times, to 300 guilders per hectare but imagine this must be a rare occurrence. The rent for dry land (tegallans) is naturally lower varying, as I was informed, from 30 to 60 guilders per hectare (Rs. 13–6–0 to Rs. 23 per acre).

2. The preliminary cultivation costs, on an average, roughly 70 guilders per hectare while the cost of applying irrigation water varies from 4 to 20 guilders per hectare.

3. The total cultivation charges for sugarcane grown on sawahs is from 150 to 300 guilders per hectare (Rs. 67 to Rs. 134 per acre), that for tegallans 60–150 guilders per hectare (Rs. 26–12–0 to Rs. 67 per acre). The cost of manure on an average of 4 cwt. of ammonium sulphate per acre and 1.7 cwt. of concentrated superphosphate per acre would work out at about Rs. 50 per acre on the basis of prices prevailing in India. This is decidedly less than the cost of manuring cane in India, where the production is at all comparable with that of Java. It may be taken that the cost of production up to the time of harvest including the cost of the rental of land and manures works out at about Rs. 350 an acre for sawahs and probably Rs. 300 for tegallans. If we deduct the rental charge it would be respectively about Rs. 275 and Rs. 260 per acre. I have not included cost of harvesting and transport and costs of manufacture concerning which I did not make any very searching enquiries.

The size of individual estates varies greatly. The smallest estate had, in 1929, an area of approximately 300 acres (121 hectares). The largest had an area of approximately 15,700 acres (6,357 hectares). It is interesting to note that, while high production per acre no doubt depends greatly on favourable soil conditions, the highest producing estates are ones of rather less than the average size. Thus the highest producing estate in 1929 with a production of nearly 9 tons of sugar per acre had an area of approximately 1,540 acres (623 hectares) under cane. The second with a production of 8.4 tons of sugar per acre had an area of about 1,127 acres (497 hectares) under cane. The third with a production of 8.38 tons of sugar per acre had an area of 2,608 acres under cane. The largest estate referred to above with an area of 15,700 acres under cane had a production of only 5 tons of sugar per acre. I was informed that a sugarcane area of about 1,000 hectares (2,200 acres) is now generally looked upon as the most economic size for an estate in Java as far as production and management is concerned. The large estate referred to is considered as decidedly too large for efficient management and I was given to understand that it is proposed to split it up into two.

The peculiar form of land tenure prevents a concentration of cane areas in very large blocks on most estates. An estate on the Malang plateau (Sempalwadak), visited by me, with an area of about 2,600 acres under cane, had a large number of comparatively small fields scattered over an area with a radius of 15 kms (approximately $9\frac{1}{3}$ miles). I heard of hauls to the factory of as long as 25 kms ($15\frac{1}{2}$ miles). While most of the cane is brought to the factory by tram lines, a good deal of haulage in bullock carts also takes place (more especially from the more distant fields to the tram lines).

If we turn to the work being carried out on the Experiment Station itself, undoubtedly that which has received the most prominence and which is, at the same time, generally looked upon as its most signal recent contribution to the development of the industry is that connected with cane breeding. Although this work has been in progress for nearly forty years, it is only within the last ten years that the station has produced a variety which has been almost universally accepted by the cane growers as of outstanding merit. This is the well-known variety POJ 2878 already referred to. A very large number of other varieties has

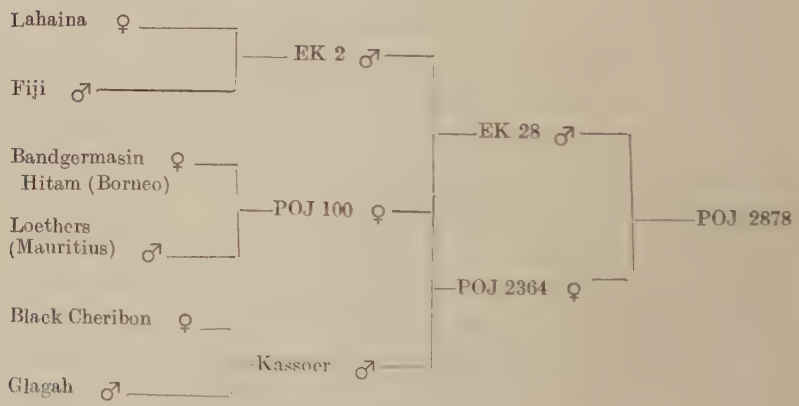
been produced on the station at Pasoeroean and, while only one of them, POJ 100, ever occupied any considerable area in Java, many have proved of great value in other sugarcane growing countries. Prior to the appearance and distribution of POJ 2878, the bulk of the cane area in Java was occupied by varieties developed by private breeders. Two of the most outstanding of these are EK 28 which in 1926 occupied 44 per cent of the total cane area in Java and DI 52 which in the same year occupied over 27 per cent of the area. It is a very striking testimony to the great value of POJ 2878 and to the wonderful organization of field demonstration and experiment work in Java that these two canes which in 1926 occupied over 70 per cent of the area under cane had, by 1930, been almost entirely replaced by the new variety which, in 1930, was estimated to occupy 98 per cent of the total area.

The breeding work which led to the production of POJ 2878 has been frequently described but as the information with regard to it is confined almost entirely to publications in Dutch and as I had an excellent opportunity to study the course that was followed, it may not be out of place to give a short description of it here. The breeding work at Pasoeroean which was started in 1893 has, from the beginning, had, as one of its main objects, the production of a cane which would be resistant to the serious disease " Sereh ", a disease for which the usual method of control was through the use of seed grown in hill nurseries at an elevation of about 3,000 feet—a decidedly expensive and troublesome practice.

Most of the early seedlings on the station were obtained by crossing the standard cane in Java, Black Cheribon, with a thin cane, Chunnee, imported from the north of India. Chunnee shows immunity to sereh and transmits this immunity to its progeny of the first generation. It is considered by Jeswiet, for many years cane breeder on the station and an authority on cane species and varieties, as a species separate from the "noble " canes (Saccharum officinarum) to which he has given the name Saccharum Barberi. None of these Chunnee hybrids developed on the station, however, came to occupy any prominence in the cultivation, partly because they gave a comparatively low yield under Java conditions and partly because they were susceptible to " yellow stripe disease ". POJ 100, the only early seedling which was extensively cultivated, did not

have Chunnee as a parent but was developed as a cross between a cane (Bandjermasin Hitam) from Borneo as mother and a cane (Loethers) from Mauritius as father.

Another line of attack was through the use of Kassoer, formerly considered as a wild cane but now believed to be a chance cross between Black Cheribon and Saccharum spontaneum (Glagah). It is interesting to note that Dr. P. Posthumus, head of the cane breeding section at the station, looks upon Glagah as very different from the Kans Grass (Saccharum spontaneum) found in India. He was, however, not prepared to say whether the differences would warrant the separation of the two forms into distinct species. This cane is immune to both sereh and yellow stripe disease, grows well, but has a very low sugar content. The crossing of this cane with POJ 100 yielded a number of promising seedlings among which was POJ 2364 the mother of POJ 2878. The father was EK 28 referred to above, the variety which, at the time, was the most widely planted cane in Java. The parentage of POJ 2878 is indicated in the following diagram :—



♀ Female parent. ♂ Male parent.

The success that has attended the introduction of this new cane has been remarkable. As stated, it has already occupied 98 per cent of the total sugarcane area in Java and, I was given to understand, has led to an increase in production per acre of approximately 20 per cent. As pointed out, however, this increase has not been due entirely to the inherent qualities of the cane, for its introduction

FIG. 6.—Varietal plots in the East Java Station—Irrigation channel to the left.

FIG. 7.—Cane varieties on the East Java Station. To the left POJ 2878 and POJ 2883; to the right EK 28. These canes are all of the same age, about ten months.

FIG. 8.—POJ 2878 cane on Krian Estate—three months old. Dr. van Dillewyn and Mr. Eggers de Bijl to the left.

FIG. 9.—POJ 2878 about five months old on the Krian Estate.

has been accompanied by two other factors which have played their part and to which I have already referred. These are an increase in the amount of fertilizers and particularly the nitrogenous ones used per acre and a general advance in the planting season. This latter, in turn, has been due partly to more adequate supplies of labour and partly to the fact that the new cane is decidedly more drought resistant and so has allowed for an earlier planting. I was, in fact, informed that POJ 2878 has scored its greatest successes in the eastern part of the Island where soil moisture is much more of a limiting factor than farther west. I gather also that its superiority is decidedly more apparent on the low lying lands near the coast than on the higher lands such as those of the Malang Plateau.

The vigour of POJ 2878 and certain other of the higher POJ numbers, especially under somewhat unfavourable conditions, is very striking. The accompanying photograph (Fig. 7) shows a small plot of POJ 2878 together with another recent POJ seedling with a plot of EK 28 for comparison. Both these plots, situated on the Pasoeroean Station, were planted in December 1929, an unfavourable season for cane planting in this area, and received the same treatment. The difference in growth is remarkable. Figs. 8 and 9 show POJ 2878 about three and five months old respectively on the Krian Estate in the Sidhoardjo delta about 30 miles from Pasoeroean and gives a fair picture of the growth of this cane on one of the best estates in Java.

Not only is the variety very vigorous with a high sugar content; it is also resistant to most of the serious cane diseases in Java. As will be noted later, however, it appears to be susceptible to some of the insect pests of cane, notably the most important sugarcane borer.

Large quantities of this variety have been exported to other sugarcane growing countries, notably Cuba and Formosa, where, as I understand, it has done extremely well. This has led the controlling committee of the Experiment Station to take the step of prohibiting the export of any further seedlings developed on the station and in fact to restrict very considerably the distribution of scientific information obtained as a result of the station's activities. If we recall the fact that the station is financed entirely by the Java Sugar Industry we can certainly not criticize the considerations which have led to this attitude whether we consider it wise or not.

of the Section, who showed me many beautiful chromosome preparations and explained to me the highly interesting and important work he is doing.

Associated with the Plant Breeding Section and, I understand, since my visit amalgamated with it, is a section dealing with weed survey. This work was under the charge of Mr. C. A. Backer who was engaged in the preparation of a monumental publication on the weed flora of Java sugarcane soils (De Onkruid Flora der Javasche Zuikerrietgronden) which is being issued in parts fully illustrated. I gather from Dr. Posthumus, who has recently visited us in Bangalore, that the weeds of our cane fields are very similar to those found in Java, so this work is likely to be of considerable value to us. I understand also that it is one of the publications of the station which is still available to the general public outside Java.

The other sections dealing with the biological side of investigation on sugarcane are the physiological, the pathological and the entomological sections.

The Physiological Section under Dr. T. H. van den Honert is, I gathered, a comparatively recent addition to the station's activities. Dr. van den Honert is working especially on the physiology of the root system, more particularly with reference to the assimilation of nitrogen, although he is also studying the requirements of the sugarcane plant as regards other plant food material also. For his nitrogen studies he is using water cultures which he establishes in the following manner. He first grows the sugarcane setts in sand for about six weeks during which time he gradually cuts away the parent sett till he has the plant established entirely on its own root system. It is then transferred to the water culture for which he has, after much experiment, worked out a suitable medium. He can grow the cane in these cultures for about five months. In addition, he had a number of sand cultures in pots where the plants were about 12 months old when I saw them (see Fig. 10). I should imagine this is the first time that the exact methods of the physiological botanist have been applied to the sugarcane plant.

Another physiologist, a lady, is engaged under Dr. Koningsberger's direction in the carbohydrate assimilation of cane but she was absent at the time of my visit.

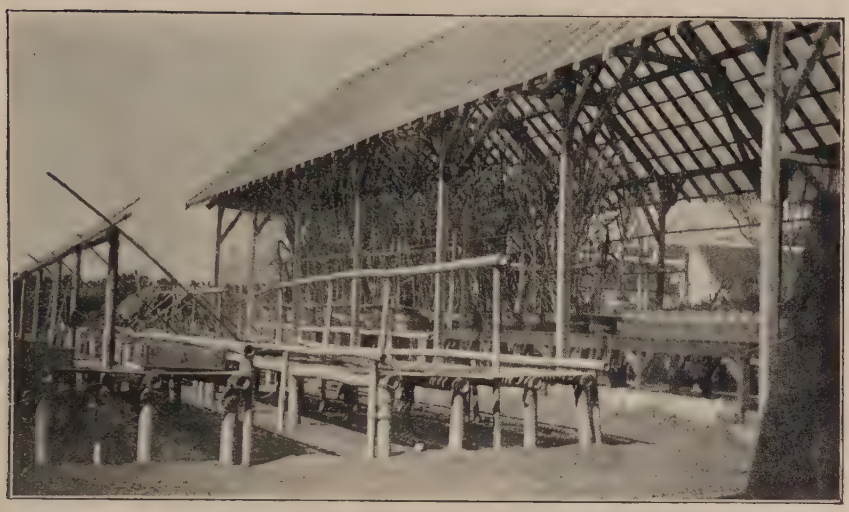


FIG. 10.—Pot culture house, East Java Station, showing sugarcane growing in the sand cultures in pots. In the fore-ground are the benches on which seedlings are raised.

FIG. 11.—Sugarcane factory, Sempalwadak Estate—Cane being hoisted from a tram wagon.

FIG. 12.—Sempalwadak Estate. Factory looking towards crushing plant.

FIG. 13.—Crystallizers in jaggory factory on the Lucas Estate. The stirrers of most of the crystallizers have been raised.

The Entomological Section is, or was at the time of my visit, under the control of Dr. E. H. Haselhoff. The most important sugarcane insects in Java, as in Mysore, are the moth borers of which the top borer Scirpophaga auriflua, Zell. var. intacta, Snell, causes the chief damage. The method of control practised is the removal of attacked shoots in cane from 3 to 6 months old, during the three months, October, November and December. These measures are carried out by gangs of coolies who go around the fields once in three weeks, the plots and coolies being numbered. The supervision is by one man to 200 hectares (500 acres) who examines four to five rows in each cooly's area once a month.

It has been established that this borer gains an entrance through the leaf midrib reaching by this means the growing point. There is a correlation between the softness of the midrib and the degree of infestation. Hence infestation is more serious in some varieties than in others and in the wetter areas (Banjoemas and Pekalongan) than in the drier areas of East Java. POJ 2878 which has a soft midrib is particularly susceptible to attack.

Other borer forms are Chilo and Diatræa species including Diatræa venustata Wlk (=striatalis, Snell) which is, according to Dr. Haselhoff, very difficult to control.

The only other serious pest is the woolly cane louse, Oregma lanigera, Zehntner. Mechanical methods and the use of insecticides have given unsatisfactory results with this pest. The most satisfactory control method so far tested has been the transfer of the parasite, Encarsia flavoscutellum, Zehntner from old to new cane fields. This method is based on the fact that the winged forms which spread the pest to new fields are not parasitized and so escape to the new fields. It is thus necessary to transfer leaves bearing parasitized lice to these fields so as to ensure a rapid distribution of the parasite.

The work on the diseases of sugarcane has been conducted up to the present on the Cheribon station and was, at the time of my visit, about to be transferred to Pasoerocan. I was unable to visit Cheribon. The published work of Dr. (Miss) S. J. Willtrink is so well known that I need not refer to it here.

The soils section is large and most admirably equipped. Its head, Dr. (Miss) Neeb, left the station on tour shortly after my arrival so I could not do more than make her acquaintance. One

At Sempalwadak we were shown over the factory, a rather old one in which machinery had been replaced from time to time. The crushing plant has a cane hoist and automatic carrier and consists of a Krajewski crusher and five sets of rolls each set run by a separate steam engine. Imbibition is by warm water on the last set of rolls and by juice from the last set to the second last and so on till the second set of rolls where it is drawn off to the defecators after weighing and liming. From here, after settling, it passes to a quadruple effect and from there through reserve tanks to vacuum pans. From the vacuum pans it went to crystallizers and centrifugals. The first sugars went to the driers and were then bagged. The second sugars were being moistened with a small amount of molasses to give them a darker colour, because there was a better market for the darker sugars at the time. Figs. 11 and 12 give interior views of the factory.

The steam was supplied from five large boilers heated entirely by begasse which is shredded in a special machine before use. The begasse furnaces were being fed by hand by native boys. Begasse and trash were apparently far in excess of the demands of the factory for they were being employed for firing the four locomotives used to haul cane to the factory as well, being pressed into bales for the purpose. No extra fuel was required for these locomotives. Though, as stated, the factory is by no means a new one, still it seems to be very efficiently run, for the rendement in 1929 was as high as 13.98, as muscovado, or 13.28 as plantation white, a very high figure indeed. The rendement for 1930 has dropped owing possibly to deterioration in the quality of cane consequent on the prolonged drought which had obtained.

From the factory we visited various portions of the estate. This, as is generally the case, is widely scattered and in comparatively small blocks. Most of these are served by tram-lines but the cane from the farthest block had to be hauled to the tram-line by bullock carts.

The soils of this estate are mainly of two types, a heavy black clay derived from the Ardjoeno, a large volcano lying to the north of Malang and a much lighter chocolate to yellowish red soil, derived from more recent volcanic deposits from the Smeroe, the highest volcanic peak in Java commanding the Malang plateau on the east.

It was interesting to learn that most of the sugarcane area of 1,150 hectares had been cultivated with steel ploughs drawn by caterpillar tractors. Ploughing is done to a depth of 12 inches after which drains and furrows are dug by hand. All these operations were estimated to have cost 30 guilders per hectare or Rs. 13–6–0 per acre.

The acting manager, Mr. Feldcamp, who conducted us throughout, said he did not consider ploughing any cheaper than the usual method of digging but he thought it gave better results. After planting, irrigation is given at the end of three days by throwing water on with buckets from the drainage-irrigation channels and this is repeated every fourteen days thereafter till the end of the fourth month by which time earthing up has taken place which allows for ordinary flow irrigation between the rows. Mr. Feldcamp stated that he would favour the beginning of flow irrigation at the end of three months. The cost of irrigation here was 32 guilders per hectare plus $4\frac{1}{2}$ guilders incidentals. The last item is significant; its purpose need, I think, not be stated. The total works out to approximately Rs. 17–9–0 per acre. Although I did not get figures for the duty of water for cane, it must, I think, be obvious that with the same amount of irrigation water more than double the area is being irrigated on this estate than can be usually irrigated in Mysore. As will be seen later, the cost of irrigation on this estate is about double that on the Krian Estate in the Sidhoardjo delta.

The chief variety grown on Sempalwadak was POJ 2878 but one of their own seedlings SW 499 as well as POJ 2883 were also being grown. The young cane I saw was from three to six months old and while fairly even, seemed to me somewhat stunted. It looked as if it had suffered from lack of moisture. The average yield per acre which during the previous year (1929) had been 174 quintals per hectare (muscovado) or almost 7 tons of sugar per acre, during the year 1930 was, up-to-date, almost exactly the same. The manure applied was ammonium sulphate in doses varying from four to eight quintals per hectare (3.2 to 6.2 cwts. per acre).

From Sempalwadak we proceeded to Krian in the upper part of the Sidhoardjo delta. The factory here had stopped work for the year so that I had to confine my observations to the cane fields on which cane was from three to six months old. The growth of cane in this whole area was very impressive, wonderfully uniform and

vigorous. The soil is, for the most part, a stiff dark clay overlying a more friable clay mixed with sand. The main difficulty here is the high water table and the difficulty of drainage and one of the most interesting features on the estate was the attempt to lower the water table by deepening the drains. These have been dug to a depth of about 3 feet in some fields or a foot deeper than usual and this had apparently had a very beneficial effect. The whole sugarcane area had been planted with POJ 2878 and looked decidedly better than the cane I had inspected earlier in the day at Sempalwadak. Fig. 8 shows a three months old field of cane on this estate. Fig. 9 gives a closer view of POJ 2878 cane about five months old. Notwithstanding this I was informed by Dr. van Dillewyn and Mr. Feldcamp that yields on the Malang plateau in general did not average less than those at the lower elevations. As a matter of fact, one of the estates on the Malang plateau stood second in production of sugar per acre in 1929 for the whole of Java. Krian was, in 1930, the fourth estate in Java as far as sugar production per hectare is concerned, the average having been 198 quintals plantation white per hectare (7.85 tons per acre). The manurial treatment on this estate was a uniform dose of 7 quintals of ammonium sulphate per hectare (5.6 cwts. per acre). The manager Mr. Eggers de Bijl, who conducted us, showed us an experiment in which he was testing the effect of phosphoric acid (Superphosphate) and potash in addition to ammonium sulphate. While a distinct effect was visible at the time of my visit, both Mr. Eggers de Bijl and Dr. van Dillewyn were of opinion that the difference would later disappear and that no significant difference would be revealed either in the tonnage of cane or in that of sugar.

Mr. Eggers de Bijl stated that his expenses for irrigation up to the present had been 15 guilders per hectare (about Rs. 7 per acre). As the rainy season was approaching, it seems doubtful if the total expenditure under this head would exceed 20 guilders per hectare. His total cultivation expenses excluding cost of manure worked out at 203 guilders per hectare (almost exactly Rs. 90 per acre). If we add cost of manure and rental of land the total would, I estimate, work out at from Rs. 225 to Rs. 250 per acre, which, considering the high yield, seems very low indeed.

The last observations in connection with sugar industry which

I was able to make were those connected with large-scale jaggory manufacture. I visited the estate and factory of the brothers Lucas in company with Dr. van Overbeek de Meyer. This is situated at the village of Ngadiredjo in the Madioen Residency. They have, as hereditary tenants, a property of 1,349 bouws (2,365 acres) of which 250 bouws (438 acres) is under cane. They grow chiefly POJ 2878 but also have an area under DI 52 largely because this cane ripens in twelve months whereas the former requires fourteen months to come to maturity. For DI 52 they obtain a rendement of jaggory of 13½ per cent whereas POJ 2878 gives them 12¼ per cent. Their average production is about 170 picols per bouw or slightly over 220 maunds of jaggory per acre (1 maund=28 lbs.). The average price they had obtained for their product, much of which is shipped to India, was 4.90 guilders per picol (about Rs. 1-2-0 per maund).

The crushing season had finished the previous day, so I was not able to see the factory in operation. This factory had been largely designed by the younger brother Mr. A. E. B. Lucas who is an engineer and who has had to make many alterations in the light of experience gained. The crushing plant consists of a 9-roller Krupp mill, the rolls being 14″×25″. The first unit has a top crusher roller. Each mill is driven by a separate steam engine. Imbibition is used on the second mill but Mr. Lucas is going to instal it on the third mill as well before the next season. The steam for power to drive mills, juice pumps and crystallizers is provided by a boiler with 1,000 square metres heating surface. With this mill he is able to get 75 per cent extraction of juice on cane which, considering the rather high fibre content of POJ 2878, must be considered as fairly satisfactory.

The capacity of the mill is 3,000 picols (182 tons) of cane per day of 22 hours but as their boiling plant cannot deal with the juice of more than 2,000 picols per day they have to work the mill at this capacity.

The juice is ordinarily pumped from the mill to open round evaporating pans which he has had to re-design. He has had them supplied with a scum gutter around the top for skimming the scum during boiling. He has also had greatly to steepen the slant of the

bottom and to enlarge the outlet so as to allow for the highly thickened mass to flow off. The bottom had in fact an angle of about 30°. Lastly, he has had greatly to increase the heating surface of the coils in the bottom of the pan. These originally had a surface of 3 square metres which he had increased by adding coils to 5 square metres in the case of evaporators with a capacity of 2,000 litres (440 gals.) of juice. He had also a series of smaller evaporators of half the capacity and, of course, half the heating surface. He uses waste steam for boiling up to the "high boil" point and then pressure steam, with the pressure gradually increasing up to 5 atmospheres as the juice concentrates.

He has also a vertical preheater, which he uses only when he is not making hard jaggory, in which waste steam is used. He told me he cannot make really good jaggory if he uses this and thought it had something to do with the difficulty of separating impurities after heating has taken place in it. It seemed to me that the difficulty probably arose from inversion owing to the slow and rather prolonged heating in the preheater. When he wishes to make hard jaggory he leads the juice direct to the evaporators.

Steam for the evaporating plant (except of course the exhaust steam) was derived from a boiler of 200 square metres heating surface.

I have already noted that the slope of the bottom of the evaporators has been greatly steepened. In addition to avoid the clogging of the delivery pipe by crystallization of the massecuite this has been replaced by an inverted funnel-like pipe much wider at the bottom than the top.

It is impossible to deliver the massecuite direct to the crystallizers by pipes owing to the danger of cooling and crystallizing during the passage. The transfer has to be made by hand in baskets or other receptacles.

The crystallizers that he uses are his own design and are illustrated in Fig. 13. These are copper pots about three feet in diameter and three feet deep with a water jacket through which cold water can be circulated. The stirring of the massecuite during cooling is done by four wooden fingers mounted obliquely on a cross piece attached to a vertical shaft. The stirring apparatus can be raised

when the crystallizers have to be emptied. It requires four of these crystallizers to deal with the massecuite from one of the larger evaporators. The crystallizers have been designed to copy the native manner of stirring massecuite during cooling as closely as possible. As will be seen from the illustration they are arranged in pairs.

The cooling massecuite has to be taken out of the crystallizers by hand with some considerable amount of expedition or it will get hard before removal.

They make two qualities of jaggory, one a somewhat soft jaggory which is stored in baskets and shipped to India. The other is a hard, so-called "cup" jaggory moulded in half shells of cocoanuts. This is for consumption in Java. As far as colour was concerned both the qualities were good and there seems no doubt that uniformly good jaggory can be made in a plant of this kind. I may point out that the Lucas brothers started making jaggory by the ordinary method but found it was quite impossible to control the processes of manufacture for the large quantities with which they have to deal, without recourse to steam. I am by no means sure that the plant which the Lucas brothers are now working is the very best that could be designed for jaggory manufacture. It is, however, certainly an efficient plant and after seeing it and the products it is turning out I feel convinced that a steam plant is necessary for any large scale jaggory manufacture such as is likely to develop in the Irwin Canal area.

Conclusions.

The conditions governing sugarcane cultivation in Java are so different from those prevailing in Mysore that results obtained in that country obviously cannot be directly applied here. However, we have much to learn from the methods that have been used and the results that have been obtained.

1. The most striking feature of the sugar industry in Java is its dependence upon scientific investigation and experiment. I have pointed out how closely the practice on estates has followed the results of accurate manurial experiments on the kinds and amounts of fertilizers to be applied. I have also pointed out the rapidity with which a new cane variety shown by experiment to be a distinct improvement has replaced the varieties previously being

grown. This prompt and general application of the results of scientific experiment is, of course, largely due to the centralized control of sugarcane cultivation but it is also, to no small extent, due to a faith in science which remains largely to be developed in this country.

2. As regards the question of sugarcane breeding, I believe the physical conditions prevailing in Mysore are even more favourable than those in Java. Sugarcane flowers and sets seed more freely on the Mysore plateau than in any other part of India. The Economic Botanist, Dr. V. K. Badami, has already made a large collection of canes from various parts of the world and has been able to evolve, through the growing of seedlings, a number of vigorous and high-yielding varieties which are extending rapidly in the State and have already spread to areas outside as well, both in Bombay and in Madras Presidency. It would seem, in fact, as if we were ideally situated for the production of new varieties to meet the requirements of India for thick canes.

The breeding work in Mysore has been greatly restricted as regards both staff and suitable area. With a small staff, such as we have, the relative importance of different crops has to be most carefully considered and while the importance of sugarcane in Mysore cannot be judged by its comparatively restricted areas, still one must not lose sight of the fact that the area is restricted to about 40,000 acres. With the development of the new Irwin Canal area it seems certain that sugarcane will greatly increase in importance in Mysore. The large sums of money involved in the development of irrigation and the very considerable outlay which the ryots of the irrigated area will be called upon to make, will place upon us the duty of providing the highest yielding cane possible. It appears, therefore, that a much more extensive and intensive scheme for sugarcane breeding is required than any we have attempted up to the present. The plan of operations at present being followed in Java is one worthy of very careful consideration in the development of any scheme for sugarcane breeding. I have already referred to the advisability of using our high class cane Pattapatti as one of the parents in such breeding work. I need hardly point out that the new large sugarcane farm at present being developed in the Irwin Canal area would furnish an ideal site for breeding

work. As, however, that farm must be run on a business basis no extensive breeding work can be attempted unless special funds earmarked for the purpose can be provided.

3. The results of the manuring and of some of the cultivation experiments conducted in Java are very similar to those already obtained by us here. It would be unwise to think of copying their methods of preliminary cultivation which are necessitated by the conditions of soil, crop rotation and land tenure prevailing in Java.

4. From the standpoint of soil and also probably of climate, conditions are decidedly more favourable for the growth of sugarcane in Java than in Mysore. That means that for the production of similar crops we shall have to apply considerably larger quantities of manure. On the other hand, the high rent paid for land in Java is an unfavourable condition with which we do not have to contend. The cost of labour is also, I believe, somewhat lower in Mysore but, if we take into account efficiency, it is impossible to speak definitely on this point. On the whole, with the protective tariff at present obtaining in this country,—a tariff which, I believe, it is safe to say will not be lowered in the near future—it should be quite possible for us to compete with Java in the production of sugar for Indian consumption.

5. The only part of Mysore where sugarcane cultivation can be organized on a scale such as to allow for the establishment of a sugar factory or factories appears to be the Irwin Canal area and the possibilities in this connection should be kept constantly in view in the development of that area. It will take several years for the sugarcane area to extend to such proportions as to allow for the establishment of a sugar factory. In the meantime arrangements will have to be made for the manufacture of jaggory on a factory scale. The new sugarcane farm on which it will be possible to grow 100 to 150 acres of cane every year will form an excellent centre for such a factory. This factory should, if possible, be planned so as to allow, by the addition of further equipment, for a change over to sugar manufacture as soon as the area under cane has developed sufficiently for the purpose. The whole scheme should be most carefully planned so as to avoid waste in equipment.

6. Any development of sugar manufacture in Mysore must, I feel sure, be on lines very different from those obtaining in Java.

It would, I think, be almost impossible for a company to obtain long leases of sufficient areas of land to allow them to grow all or even half of the cane required for a factory. Even were this possible, I am by no means sure that it would be advisable from the standpoint of the agriculturists who are the people whose interests we have mainly to consider. I believe, however, that it should not be impossible to establish a sugar factory in this area growing part of its own cane and purchasing the balance from the ryots. The system of irrigation which is being introduced will, if successful, I believe, practically ensure a regular supply of cane in sufficient quantities. I am further of opinion that the crushing of this cane in an efficient central mill or mills and the manufacture of jaggory or sugar in central factories should give a larger net return to the ryots than were they to attempt to crush their own cane in bullock mills and manufacture their own jaggory in the crude manner now generally practised. The whole question of the development of sugarcane cultivation and the manufacture of jaggory and sugar in this area is intimately connected with the questions of the supply of capital, manure and seed. All these questions are ones which will require all of the attention which the recently constituted Krishnaraja Sagara Working Committee can devote to them. They are extremely difficult ones but, I believe, they are not insoluble.

NOTES AND COMMENTS.

Notes on Sugarcane Cultivation in Java.

This report giving the results of observations made in Java during October 1930, is appearing very much later than I had originally planned. The delay has been due partly to ill-health and partly to heavy work which has prevented the writing up of my notes as rapidly as I had hoped. Some of the information contained in it is therefore to a certain extent out of date. However, as it is very largely first-hand information, it seemed to me advisable to include it more especially as much of it is not readily available to those interested in Mysore agriculture.

The report is a modest one and does not in any way pretend to contain an exhaustive discussion of sugarcane cultivation in Java. The time I could devote to this subject was very limited as the main object of my visit to Java was to study questions connected with another important Mysore crop, coffee. My observations were moreover made definitely with reference to the conditions existing in Mysore and any conclusions I have reached have been with reference to those conditions and more especially to those that have been created recently by the construction of the Irwin Canal which will ultimately irrigate 120,000 acres of land in the Mysore District.

It is generally recognized that very high yields of sugarcane can be obtained in this State and that the best of our canes have a very high sugar content. Yields of sixty tons of cane and of over six tons of jaggory to the acre have been registered and we have several cane varieties which, under optimum conditions, will produce yields of this nature. That our average production is rather less than twenty tons of cane per acre is due, in great part, to two causes. In the first place, as most of our cane is grown in comparatively small patches under tanks, irrigation water is very commonly a limiting factor in production while faulty drainage also plays a rôle in reducing yields. In the second place, our sugarcane growers commonly cannot command sufficient working capital to purchase manures in sufficient quantity to produce high yields. Even if they could, the danger

of failure of irrigation water at a critical period quite commonly makes the investment of large sums in manures a risky venture.

Under the Irwin Canal we shall have, for the first time in Mysore, a large and assured supply of water throughout the year and this will provide us with one of the essential conditions for intensive sugarcane cultivation. If the agriculturists of the area can be supplied with adequate working capital for the expenses connected with the purchase of manure and with the provision of adequate cultivation, it should be possible to bring our acreage production in the area profitably up to forty tons of cane to the acre. With the breeding and introduction of still higher producing cane varieties we should, I believe, be able even to exceed this figure.

This report shows some of the directions along which intensive work will have to be carried on if we are to reap anything like the maximum benefit from this grandly conceived irrigation scheme. It will require the best that this State can furnish in the way of brains and energy from both non-officials and officials if we are to crown the labours of our irrigation engineers with that agricultural success without which those labours will remain fruitless.

In the report will be found reference to most of the scientific workers and sugar planters from whom I obtained the information and assistance which enabled me to cover much ground in a short time. To these and to others I wish to express my thanks. I must thank especially Dr. V. J. Koningsberger, Director of the Agricultural Section of the East Java Sugar Experiment Station, for his guidance without which I should have been able to accomplish but little.

Leslie C. Coleman.

SELECTIONS.

Award of Prizes and Medals for Improvements in Agriculture and Animal Husbandry.

Letter No. 1673/*Agri. dated the* 20*th July* 1931 *from the Secretary to the Imperial Council of Agricultural Research, Simla, to all Local Governments, etc.*

I am directed to refer to paragraph 150 of the Report of the Royal Commission on Agriculture in India in which it is recommended that the Government of India should award an annual prize for the most striking agricultural improvement of the year.

2. The Imperial Council of Agricultural Research to whom the question was referred by the Government of India for such action as may be considered suitable, decided to allot from its funds Rs. 10,000 per annum for five years to be distributed annually subject to there being exhibits of the requisite merit as a money prize or prizes for the most striking agricultural improvement of established merit. As it would be difficult to adjudicate on exhibits relating to different subjects, for example, between an improved field implement and an improved veterinary scientific instrument, the subjects for which in turn a prize was to be awarded, were arranged in five groups. All the groups were to be announced at one time but a prize for one group only was to be awarded in any one year beginning with 1932. It was tentatively decided that the groups should be as follows :—

(*i*) Veterinary scientific instruments and appliances.
(*ii*) Dairying and the care of animals.
(*iii*) Field implements and appliances.
(*iv*) Machinery for preparing crops for markets, for food or for storage.
(*v*) Water lifts.

For example, under group (*i*) would be exhibited an improved veterinary surgical appliance ; under group (*ii*) an improved silo design ; under group (*iii*) an improved general purposes seed drill or an improved yoke for cattle ; and under group (*iv*) a groundnut decorticator.

3. The Council also decided, in case suitable exhibits were forthcoming, to award each year gold and silver medals for improvements of distinct merit in the science and art of agriculture and animal

husbandry. One gold medal open to all-India will be awarded for an improvement of all-India importance while two silver medals will be earmarked for grant in each province (including Indian States which are or may in future become constituents of the Council) for improvements which are in the main of provincial importance. Improvements of real merit in animal and plant genetics, field engineering, crop protection, etc., are instances of the kind contemplated which will render the inventor eligible for the award of either a gold or silver medal as the case may be which will be awarded in the name of the Council.

4. The details in connection with the scheme outlined above have not been worked out as yet : but on a careful reconsideration of the whole question, the Imperial Council has since decided that before embarking on an ambitious scheme for the award of a money prize, referred to in paragraph 2 above, costing in the aggregate Rs. 50,000 some experience should be obtained as to whether the expenditure involved will achieve the desired ends. In this connection, I am to enclose for information a copy of this Department letter No. 2480/Agri. dated 21st November 1930 regarding the award of a prize for a bone-crusher, worked by (*a*) animal power and (*b*) by mechanical power. The results of the competition for the design of a suitable bone-crusher will be a valuable guide in this connection and it has accordingly been decided that these should be awaited before the scheme for an All-India money prize is launched.

5. The case for giving effect in the near future to that part of the scheme which relates to the annual award of gold and silver medals is however stronger. Such medals will, as the experience of the Royal Agricultural Society in England has shown, provide at a comparatively small cost a stimulus to improvements in the science and art of agriculture and animal husbandry.

As a first step in carrying out the proposal set forth in paragraph 3 above, I am to enquire whether the local Governments also favour this proposal and if so, whether the local Governments agree to the following procedure being adopted for the submission of entries :—Entries to be submitted in the first instance to the Provincial Research Committees which will forward to the Council those which they consider the most suitable, the Provincial Committees at the same time sending to the Council a description of rejected entries.

Copy of a letter No. 2480/Agri. dated the 21st November 1930 from the Secretary, Imperial Council of Agricultural Research, to all local Governments and Administrations.

The Fertilizers Committee appointed by the Imperial Council of Agricultural Research considered at its first meeting held at Simla in June 1930 suggestions in regard to cheapening the production of bone-meal and extending its use for manurial purposes in India. In this connection, the Committee recommend, *inter alia*, that the Council should offer a prize of Rs. 3,500 in each case for a bone-crusher worked (*a*) by animal power and (*b*) by engine power and that, as far as (*b*) was concerned, the following general conditions should be laid down for the prize :—

(*i*) Cheapness, durability and simplicity of adjustment should be the factors governing the grant of a prize.

(*ii*) The exhibit should constitute a material advance over the pattern already on the market.

(*iii*) The engine for working the power-driven crusher should be of the power of the smallest engine commonly used for lifting water or crushing sugarcane.

(*iv*) The successful competitor should undertake to give licenses for manufacturing in India at a royalty not exceeding 10 per cent of the cost of manufacture.

2. The Council has decided to award the two prizes and has issued Press Communiques on the subject, copies of which are attached for your information. If the local Governments have no objection, I am directed to request that steps should be taken to give the widest publicity to the award of the two prizes.

PRESS COMMUNIQUE.

The Imperial Council of Agricultural Research offers a prize of Rs. 3,500 for the design of an improved bone-crusher to be driven by a small engine and suitable for the production of finely ground bone-meal for manurial purposes. Competitors should submit detailed scale drawings which must be sufficiently complete in all details to enable any manufacturer to make the crusher. To be eligible for the prize a design must comply with the following conditions :—

(1) The design must be a material advance over any pattern of bone-crusher at present on the market ;

(2) The crusher should be capable of being worked to its full capacity by an oil-engine of 12 to 15 B.H.P. or a similar prime mover ;

(3) Cheapness, durability and simplicity of adjustment are essential and no design not satisfying these conditions will be eligible for the prize ;

(4) The successful competitor will be required to give an undertaking to give licenses for the manufacture of his design in

India at a royalty not exceeding 10 per cent of the cost of manufacture.

Drawings must be submitted to the Secretary, Imperial Council of Agricultural Research not later than 1st November 1931.

Drawings will be examined by experts appointed by the Imperial Council of Agricultural Reseach and one or more designs may be chosen, from which the actual crushers will be constructed for test purposes. Any competitor may be required to manufacture a crusher, or any parts thereof, according to his drawings. The cost of such manufacture would be borne by the Council up to a limit of Rs. 500 each including delivery and erection at the station chosen for tests.

The prize is open to all irrespective of caste, creed or nationality and Government servants are eligible to compete for it subject to the consent of the Government under whom they are employed. The Council reserves the right to withhold or postpone the award of the prize if no entry is of sufficient merit, or to divide the prize. The award of the judges appointed by the Imperial Council of Agricultural Research will be final and all entries will be accepted on this condition.

Forms of entry can be had on application to the Secretary, Imperial Council of Agricultural Research, Imperial Secretariat, South Block, New Delhi.

NEW DELHI,
The 20th November 1930.

Some Principles Useful in Solving Economic Biological Problems.

BY W. DWIGHT PIERCE,

Entomologist for Victorias Milling Co. and North Negros Sugar Co., Victorias, Occ. Negros, Philippine Islands.

The economic biological problems as yet unsolved in the Orient are many and of vast importance. Here, more than in any other part of the world, must every inch of land yield its utmost. Every endeavour must be made to count, if we would raise the general economic level.

The methods of agriculture are primitive, sanitation is but in its infancy; insects, diseases, rodents, pests of many kinds filch huge proportions of the potential products. The natural resources available for industry have hardly been touched. Hence the economic scientist must work side by side with the research scientist, putting the results of research into practical application.

The writer has for many years been engaged in both technical research and practical application, but in his present position finds the applied features must be uppermost. The scientist engaged by an industrial

concern is expected to obtain results, and the sooner these results are visible, the more successful is his work. If he is working with a crop that is being injured he must endeavour to stop the injury as quickly as possible so that the maximum possible yield shall be obtained. Theories, methods used elsewhere, must often be rudely set aside and the action suited to the emergency. Time is more important than cost. Therefore it is of utmost importance that the scientist be thoroughly versed in the primary laws and principles of nature, for these principles govern the things he is studying. Ignorance of these principles, or ignoring them, may result in abject failure, while knowledge of them may lead to quicker results than were expected.

I shall endeavour to bring together some of the principles which I regard as of great importance in arriving at true solutions to economic biological problems. There will not be time to argue the case of each principle, so each statement is made as simply and clearly as I can make it.

1. We live in a universe which acts under uniform laws, and the principle of unity is supreme. There is system, and correlation even where we least expect it.

2. All things in the universe are definable in terms of time, space and force, and hence we have a universally applicable system of measurement, which is specifically applied in the well-known centimetre-gram-second system. If we correlate our observations to this standardized system, wherein the gram weight stands for the measure of force, we shall find that we can more readily chart and compute results, and also derive proper rules of action. Accuracy of measurement of all our factors is essential. In fact the biologist to-day must thoroughly understand the fundamentals of mathematical interpretation.

3. All entity in the universe is definable as matter, energy or life, and the total volume of these is unchangeable, according to the well-known principle of conservation. But our latest discoveries in science have shown the probability that these entities are ultimately identical and are interconvertible.

4. The acts of life are intelligent, for the organic body is essentially ruled by an intelligent master unit. The degree of intelligence is of great concern to us, in the application of our results. This applies both to the object of study, and the human element that must apply the results.

5. The entire universe is in a state of flux. Nothing is stationary. No form of living creature remains in the same groove perpetually. Evolution is one of the great vital principles. But evolution is not an aimless affair. It involves three things—matter, or an entity to be changed; life, or intellect, to direct the change; force or motion, to effect the

change. Often the phenomena we are studying are changing as the result of environmental forces. Especially among insects do we find new habits, new food plants, resulting from farm practices. The struggle for existence must be taken into account.

6. Matter, energy and life resolve into the same basic gravitational and electronic units. It is very important for us to realize that the chemical elements form a consistent series built up of various proportions of electrons and protons: and also to realize that the electron unit of matter is the electron unit of radio, electricity, heat, light, ultraviolet, x-ray, and the radiations of the elements.

7. All living organisms, plant and animal, are probably of identical unicellular origin, formed on two main lines of descent. This unity enables us to classify all living creatures in one consistent phylogenetic system of life. This fact is of utmost importance in economic work, for relationship gives clues to habits.

8. All entities in the universe are interdependent, and intimately correlated. In other words all things are dependent upon their environment.

9. The three dimensional measure of the life of an organism may be considered to consist of the line of hereditary force, forming with environmental space the two dimensional condition of any moment, these two dimensions, with time, composing the volume of life.

10. In the relationships of any two entities there is either harmony or disharmony. It is seldom that the economic scientist is called for when a state of harmony exists. He deals mainly where there is lack of harmony, and his problem is usually to restore the balance. An important thing in the question of harmonics is the fact that corresponding points in any octaves of frequency, wave length, velocity, or volume are harmonic. There are times when the harmonic relations of chemicals or other forces may offer definite means of control of noxious pests. One of the most important points to look for with regard to harmony is the acidity-alkalinity relationship. If you can determine the normal harmonic relationship of an organism to the oxytoscale of pH factors, you have immediately the key to its preservation or its destruction, as indicated by the law of limits set forth in paragraph 13.

11. All things tend towards a state of equilibrium. Equilibrium is the result of the equalizing of paired or balanced forces. The action toward equilibrium often is manifested by alternate momentum and inertia as in the pendulum. The living creature is a balance between the momentum of environment and the inertial force of heredity. Marchal's Law of Numerical Equilibrium must be thoroughly understood by the

scientist using one species to fight another. This law states that as the numerical status of the parasite approaches the numerical status of the host, the latter goes on a decline, which results in the decline in the numerical status of the parasite, until both are at low ebb, but the host is first to recover and its numerical status increases, followed in turn by that of the parasite. It is a case of rhythmic relationship. Under normal and natural conditions the parasite cannot reach total annihilation of the host. After the host is almost vanquished we notice a rise in its numbers and the comparative absence of parasites. Then is when the economic entomologist must strike, by bringing reinforcements to the parasites, so that this upward curve of the host may not further advance. We must know at every step the numerical ratios which exist between host and parasites.

12. There is a happy medium, or optimum of environment for each and every phase of existence. This is a very vital principle, and must be applied in any given problem to every force of the environment. By these forces is meant, heat, light, sound, electricity, x-ray, ultra-violet; gravitation, which includes atmospheric pressure and relative humidity; chemicals, which include soils, acidity-alkalinity; and finally the specific forces, plant and animal. The application of the principle extends to velocity, frequency, wave-length, and volume.

13. On each side of the happy medium are zones of decreasing effectiveness, approaching the maximum and minimum limits of endurance. The law of limits applies to everything, and the ascertaining of these limits is often the quickest way to answer a problem, where control is desired.

14. All actions are the results of the interplay of antagonistic forces. Action causes reaction. All action is in the direction of equilibrium. The determination of reaction leads the scientist to find the forces which will cause the necessary reaction to accomplish solution of the problem.

15. Rhythm is a universal phenomenon, a phase of harmonics. Action is reversible and rhythmic in function. Herein lies the explanation of forces, such as light, x-ray, radium, etc. Continued application of force brings about an action in one direction up to a certain point, and then the action reverses. Time is an essential factor in the application of force. The entire success of a project may be ruined by going beyond the turning point. As the time of application of a force is a measure of the volume we see how the law of the happy medium applies to time. It was partly because of this principle that the method of applying parasites in my sugarcane insect problem here in the

Philippines was modified from the old time method of releasing great volumes of parasites of the eggs in a few fields, to the release of small numbers in every field. Great volumes of short development period species with high rate of numerical increase, would quickly exhaust the potentiality of the release areas, and lead to the perishing of multitudes; while the release of small numbers allows the normal high rate of numerical increase, and accomplishes a quicker general state of equilibrium.

16. All action is in the direction of least resistance. The volume of reaction is limited to the necessity. Application of biological remedial measures over a limited territory with lack of similar action in adjoining territories results in temporary relief in the given area, but the permanent effectiveness is entirely a question of the volume of area involved. An area free of pests adjoining an area well stocked with them offers a spot of least resistance, and consequently requires long continued application of measures which would have been quickly effective in a general application. The economic man must endeavour to obtain large-scale co-operative effort if he would succeed. Another application of this principle is in the determination of spread of dangerous species. Areas of plentiful food supply offer least resistance, while areas of sparsity of food offer great resistance, hence the movements of a disseminating species are absorbed in a smaller zone in presence of plentiful food than in sparse food zones. This knowledge is vital to the men directing eradicative programmes.

17. Each entity is, of necessity, modified and adapted to its environment. Mutual adaptations are consistent with the principle of least resistance. Tolerance is a result of adaptation. In the use of poison against pests insufficient toxicity generates increasing tolerance.

Bearing these basic principles in mind, the scientist on being presented with a problem must bound his entity to be preserved, safeguarded, cultivated, improved, or destroyed, by its environment—material, physical and vital. He needs must take as accurate record as possible of the physical conditions of the atmosphere and soil. He must learn each successive phase in the cycle of existence of his central factor, and its relations to every succeeding phase of environment.

Time is an important factor in economic problems. The shortest period of time necessary to arrive at a correct diagnosis of the situation is the only truly permissible time allowed an economic worker. He can diagnose his problem long before he can devise the cure.

His second step is to outline the most feasible and economical course of action, which would lead toward the solution of the problem.

His third step is to find and propose alleviating measures at as early a time as possible, so that the remedying of the situation may proceed side by side with his efforts to find the final solution.

He must find some numerical system of keeping an accurate status record of progress toward solution, for without such information extraneous unconsidered factors may greatly alter or negative the results.

I was asked to prepare a paper on sugarcane insects, because of the probable similarity of Chinese and Philippine cane insects, but I chose rather to outline the principles that should be followed.

Sugarcane insects all over the world are closely related in types, but differ in species. They consist of root grubs (Scarabæidæ), wire worms (Elateridæ) and other root-feeding insects, young shoot borers which cause deadheart (Lepidoptera), cane borers (Rhynchophora, Lepidoptera, Cerambycidæ, Scolytidæ), bud worms, leaf-eating caterpillars, beetles, and grass-hoppers, leaf miners, sucking mealy bugs, aphids, white flies, and leaf-hoppers.

The developmental period of each is determined by the complexity of the physical environment, succulence of the food, temperature, humidity, pressure, light ; is most rapid at the happy medium, and slowed by departure of any of these factors from the happy medium in either direction.

With soil-dwelling species, we must remember that the measure of the air conditions is not criterion of the soil conditions, and that this measure must consider soil temperature, soil moisture, porosity, or texture of the soil, soil acidity-alkalinity.

Each species has its enemies ; parasites, predators, fungus and bacterial diseases, and vertebrate enemies.

The numerical abundance and damage of species depends upon the variety of cane, the other host plants and their proximity, the physical condition of the food plants, the abundance of enemies, and man's cultural and poison control measures.

The remedial measures indicated are dependent upon the above facts. In general these may be classed as follows :—

Cultural Methods :

Selection of clean seed cane.

Thorough preparation of the soil.

Avoidance of ratooning in case of abundant soil pests.

Destruction of all weeds and grasses around and in fields.
Good cultivation.
Stripping off dead leaves.
Destruction of all trash.
Stimulation of the plant by proper fertilization.

Mechanical Methods :

Hand picking of beetles, larvæ, eggs, moths.
Cutting of dead shoots.
Topping and burning of stalks bored by top borers.
Bait traps.
Sweeping with nets for grasshoppers, etc., in an invasion.
Rolling the ground to crush invading insect armies.
Barriers of ditches, water, chemicals, fire against invading armies.

Chemical Methods :

Spraying, dusting, or grassing (but only in emergency for sugarcane is a crop which is ground for food and poisons might adhere and be carried into the final product).
Inoculation of soil with chemicals for ground species.
Use of lime to alter soil acidity and thus control species native to acid soil.
Use of fertilizers for plant stimulation.

Biological Methods :

Distribution and redistribution of parasites, predators and disease germs.
Introduction and fostering of beneficial birds.
Protection of harmless snakes which feed on insects.
Development of immune cane varieties.

No matter what the pests of sugarcane or any other crop may be in China or any other part of the world, this programme of action will involve the major methods available for use, and it will be safe and feasible and in fact advisable to inaugurate the cultural method system immediately in all crops, while seeking more rapid methods of control by the other systems.—*Lingnan Science Journal*, Vol. 7.

Factors influencing Root Development in Rice and some Consequences.

It has been already recognized as a most important factor in the development of plants, that growth of roots should not be hindered by any obstacles or by any adverse conditions. Experience has taught

the farmer that the yield of crops depends in a large measure on the development of the roots.

Agricultural practice therefore has always sought for means to remove obstacles which the roots might encounter in the soil and to provide the best conditions for their development. We may assume that this happened not only in Europe, but also in the Asiatic countries, where rice growing is the most important industry, but which requires soil conditions totally different from those to which the European farmer is accustomed.

It has been thought that rice could develop different types of roots, according to conditions : those grown in a dry soil comparable to our common grain roots, and those grown in a muddy soil comparable to the roots of swamp plants. A careful examination of paddy roots of different types has shown, however, that they do not resemble those of typical aquatic plants, but are similar to those of ordinary dry land crops.

Root development of dry-land plants has been promoted in agricultural practice by different means : by removing physical obstacles (such as hardpans), by improving æration by tilling operations, by drainage, and by manuring. The choice of devices to obtain favourable conditions depends largely on the character of the soil and topographical limitations. Aeriation of the soil is usually most pronounced in soils of a sandy character and least in heavy clays and loams. Drainage is usually required more urgently in the last. By manuring with organic material soil structure is improved, so that penetration of roots is promoted. After the farmer became accustomed to the use of artificial fertilizers, it was found that different chemical substances have a different influence, phosphoric acid having a stimulating influence on root development.

It is known that root development in relation to that of the stems and leaves is more pronounced in poor than in rich soils and that the same is true when soils of different grades of humidity are compared, the drier soils forcing the plant to develop a larger root system.

That rice as a dry land crop does not differ in these respects from other grain-plants has recently been proved by Sethi (1). He planted rice in pots in different soils, under different manurial treatment and determined at different intervals the quantities of dry material of root and shoot. In this experiment two different groups of varieties were represented : early and late manuring ones. By fixing the root ratio of the unmanured plants grown on loam soil at 100, the results of the experiments on the influence of manuring may be summarised as follows :—

Days after sowing.	No Manure.	Stable manure.		Amm. Sulph.		Superphosph.		Muriate of Potash.	
		Early.	Late.	Early.	Late.	Early.	Late.	Early.	Late.
15 ..	100	68	150	85	73	128	130	150	217
30 ..	100	158	70	61	19	70	116	166	70
45 ..	100	100	110	59	49	143	205	132	213
72 ..	100	81	108	75	50	125	270	94	180
99 ..	100	..	50	..	37	..	55	..	81

There was a very large difference in the production of dry material between the pots that did not receive manure and the others, indicating that the loam used in this experiment was very poor. It may be questioned therefore if the experiment should not have given other results when richer loam had been used or when the action of different manuring had been deducted by comparing complete manuring with different combinations, omitting the principle whose action was to be determined. The results, however, confirm those already obtained with other grains, *viz.*, that phosphoric acid stimulates root production and that nitrogenous manure favours development of shoot.

Another set of pot experiments was concerned with the influence of different soil types. Some pots were filled with gravel, others with sand, loam or clay, and two other sets with clay and sand in such a way that the upper layer of one set consisted of clay with a subsoil of sand, and the other of sand with a subsoil of clay. No manure was given.

After a short time, however, the plants growing in gravel and sand died, apparently for lack of manure. The production of dry material on clay and loam showed large differences. It may therefore be questioned if the differences found by this experiment are due to the differences of the types of soil as such, or to differences in content of manuring principles, the clay being a very rich soil the other soils being poor or very poor. It seems, therefore, that these experiments do not allow of any conclusion on the influence of soil type. Only when differences in richness are excluded can the action of differences in physical character be deduced from the results.

The question of root development of rice under aquatic conditions, the most important question in relation to rice growing, is, however, quite different from that of root development of grain plants grown under dry land conditions.

Irrigated Rice-growing and Æration of Soil

As the roots of rice grown under aquatic conditions do not resemble those of aquatic plants, but are similar to those of ordinary dry land

crops, they require oxygen to be healthy and strong. This oxygen can be brought to them only as a solution in the water that surrounds the roots.

If the oxygen dissolved in the surface water is to ærate the roots drainage would seem to be an important factor. If the soil is badly drained the oxygenated water cannot enter the soil and consequently æration would be restricted to the surface layers ; and on the other hand, in well drained soils, the ærated water would penetrate deeper, allowing the rice plant to develop a larger root system and therefore a proportionally higher crop. If this is the case æration can be promoted by a thorough periodical draining of the soil.

There are however several agricultural practices that do not conform to this theory.

In many of the rice-growing countries a hardpan is formed by the action of the irrigation water only a little below the surface and farmers take much care not to break this hardpan. Even more remarkable is the fact, that in new rice fields where such a hardpan is not found, puddling is a universal practice, by which a more or less impervious layer is artificially formed. Sometimes this is done by men, but in several places it is done by driving cattle for a considerable time over the irrigated plots. It may be, that the purpose of this practice is to prevent the loss of irrigation water by drainage, in this way making it possible to irrigate a larger acreage with a given quantity of water. But the practice is also found where it cannot be explained thus. It will be seen later that another explanation has been found, that throws fresh light on this question.

With regard to the question of periodical drainage, in some parts of the rice-growing countries it has been practised generally and in others it is not known and experiments have given contradictory results. In Sumatra, for instance, it is a common practice, in Java not.

Khoi (1) gives some valuable information in regard to the practice of rice-growing in the Van-Trai region of Indo-China. Irrigation water is given from the start, to allow the forming of a thin mud by repeated ploughing and harrowing. Water is covering the field during transplanting, till the tillering process has ended, when the water is allowed to flow off. As soon as flowering commences .water is given again till the time of fruit setting. This practice is the same as in the larger part of Sumatra, but in Java water is given from planting till a short time before harvest, and this method is followed in many other countries

We may ask whether the application of one method or another depends on the kind of soil or whether different varieties also require different treatment.

That soils influence the practices in rice-growing is without question. Khoi in the article cited gives also a description of rice-growing on fields formed by marine sands in the same region. Here the soil is not worked into a mud but ploughed and harrowed in a dry state and rice is transplanted without irrigation. No water is given till the plants have reached the stage at which the soil is no longer visible. In the time before irrigation starts, several hoeings are given. At this stage of development hoeing is regarded as more valuable than irrigation. This is quite right, for such sandy soil becomes very compact under water, in this way preventing æration and root development.

Under aquatic conditions certain sand soils provide bad æration and some heavy clays, that easily form a thick layer of thin mud, facilitate it, in this way reversing the æration conditions of the same soil types in dry conditions.

It would be unwise, however, to generalise. For several sandy soils give perfect æration when irrigated and several heavy clays offer very poor æration. An example of the first may be found in the residency of Tapanuli in Sumatra and of the last in the residency of Demak in Java.

In the Netherlands Indies rice varieties are divided into two main groups, according to morphological and physiological characters. One group does not respond favourably to periodical drainage, of the other group many varieties require it to give a maximum yield.

Summarising we may say, that agricultural practice, developed by centuries of experience, has developed features which seem to be contradictory to the æration of soil, such as puddling and uninterrupted irrigation, though we may assume, that where this is practised, root development is promoted.

Use of Fertilizers.

Viswanath (2) in a short but a very suggestive article gives the results of valuable investigations in rice-growing in the Madras part of India.

The general results of manuring experiments have been that nitrogenous and phosphatic manures are in general need and are responded to by the crop when applied singly or together, but their effect when combined is better.

Phosphatic manures have been found to stimulate the assimilation of nitrogen which would otherwise not be utilized.

It has been shown that artificial manures are not as efficient as green manures for paddy and that the efficiency of either class of manures can be considerably improved by combining them. This raises the question as to the proportion in which artificials and green manures should be used. Large dressings of green manure appear to render supplements of artificial nitrogen, like sulphate of ammonia, ineffective.

The results of a large number of experiments in the field and in pot cultures spread over a number of years have shown that all the natural and artificial nitrogenous manures are more or less beneficial to paddy *but that they are more economical when applied in conjunction with bulky organic manures.*

Problems of Green Manuring.

Results of green manuring experiment on paddy fields have been of the most contradictory character, in many cases they have been satisfactory, but many too have given negative results.

Since green manure undergoes putrefactive fermentation under water, it was considered that an examination of the soil gases would open up the problem. On this examination Viswanath gives much information.

The first examination showed that the normal fermentation of green manure in swamp paddy soils leads to the production of different gases and that the introduction of a crop into that field modifies the proportion in which some of the gases are produced and inhibits the production of others. The soil conditions are found to be anærobic in character and therefore nitrification is impossible and nitrates produced during the period when the soil was dry are quickly denitrified. Under these conditions, therefore, the nitrogen required by the crop is obtained in the form of ammonia and probably from other nitrogenous organic compounds produced by the anærobic decomposition of the proteins in the green manure.

This gives a very important practical indication : that growing a green manure crop in a field to which it has to be subsequently applied as a green manure in a dry condition is not advantageous, as the nitrogen is largely dissipated as gass. This is especially true when a non-leguminous plant is used for green manuring, for, as this crop has taken its nitrogen originally from the soil, it involves a distinct loss of nitrogen.

Certain substances formed as a result of this decomposition are toxic to the rice crop and should be removed in the drainage water or

should be destroyed by prolonged decomposition before seedlings are transplanted.

This result is in correspondence with agricultural practice. Oriental farmers know, that the best method of preparing a paddy field when submerged and covered by a more or less dense vegetation is, to give it a rest after the first ploughing before the finishing operation is started. The duration of this rest differs considerably. In Sumatra, where spontaneous vegetation on the rice field is mostly very luxuriant, a period of at least three weeks is considered the best. But when a paddy field not covered by vegetation has to be prepared, this period of rest is not considered necessary.

A more detailed study of the soil gases revealed the fact that the gases escaping through and at the surface of the water in the paddy fields are different from those that are present in the soil and consist mostly of oxygen and nitrogen as against methane, hydrogen and carbon dioxide that are formed in the soil. A certain relationship was also noticed between the evolution of oxygen and the presence or absence of a rice crop, and pot experiments have clearly shown that the effect of this crop is to diminish the evolution of oxygen. The supposition is, therefore, correct that the oxygen is used for æration of the roots.

The evolution of oxygen has been traced to a film of algæ commonly seen on the soil surface of paddy fields and this film is found to contain bacteria which oxidise hydrogen and methane with production of carbon dioxide. The carbon of this gas is utilized by the alga for food, liberating oxygen which dissolves in the soil water and ærates the roots.

It appears reasonable to presume that the better the drainage the deeper would be the æration and therefore the better the development of roots and the results of cropping. But actual experiments have shown that this is not the case. The mere draining of the soil is inadequate for this purpose.

The simple system of slow movement of water through the soil and therefore through the root range has been found to be most beneficial for the crop. The reason for this has been found to be that the water percolating through the soil is strongly charged with oxygen and therefore supplies it to the roots; whereas the simple admission of air into the soil by thorough draining would yield only a weak solution of oxygen. The best results are obtained with a moderate amount of drainage and too slow or too rapid drainage would result in decreased yield.

The reason for this has been traced to the fact that the development of the film which is responsible for the supply of oxygen occurs

best under moderate drainage conditions. Thus the most efficient drainage in paddy fields is not the quickest but one that permits the surface film to maintain its full activity.

The practical aspect of these investigations from the point of view of the farmer is that the relationship of green manure to the æration of roots is of the greatest importance and that, apart from all other considerations of manurial value or influence on the texture of the soil, *one of the most important functions of green manuring with reference to paddy soils lies in promoting the activity of the surface film, which is responsible for the proper aration of the roots.*

It is in this way that an explanation may be found of the influence of bulky organic manures on the results of manuring with artificial fertilizers. The first by their biological influence promote the development of the root-system and this enables the plant to make use of the non-organic food offered by the second.

It is however of interest to note that agricultural practice in several cases is in accordance with these findings. The practice of puddling, questionable before this discovery of the algal flora and its biology, fits remarkably well in this system; it would be very doubtful if it is possible to develop a better device to retard drainage on hillside terraces.

Another practice often to be seen in sparsely populated regions with plenty of water is to restore the small dykes surrounding the fields after harvest, to cut down the remaining straw and submerge the fields. It has been thought that by this practice soil conditions would be harmed by lack of æration, but it now seems to be in accordance with science. In other places, heaps of coarse organic material are put on the field after harvest, which is submerged again, and small fish are brought in, which feed on the algæ that develop on the heaps and in the bottom. This practice has often been rejected on account of its supposed bad influence on soil conditions, but this now seems unwarranted and indeed crop results already have justified the practice.

Some observations made in Java are in accordance with this theory. In the eastern parts of this island a very large acreage is devoted to fish-ponds. By accident it was found that molasses of sugarcane had a very beneficial influence on the development of the blue algæ on which the fish feed, and thereby on the fish crop. It also has been found in Java that molasses used as a fertilizer on paddy fields gave very good results on heavy clays and light sands both usually giving poor crops. The explanation given was not very satisfactory but combining the influence of molasses on the rice crop and its influence on the development of

algæ in the fish ponds, it seems, that the first action may be explained by the promoting of algal flora on the rice field surface and better æration of the roots of the paddy, molasses taking here the place of bulky organic matter.

Nguyen-Cong-Tieng (1) in an article on the remarkable practice of using an azolla propagated between the young rice as a green manure, remarks that after the death of the azolla and its decomposition the colour of rice improves very much, turning from a yellowish green to a dark green. This change in colour he attributes to the nitrogen becoming available for the rice by the decomposing of the azolla. It seems, however, that it also may be attributed to a better æration of the soil, as a bad æration also causes the leaves of the rice to turn yellow.

Several questions arise as a sequel to these investigations and the theory built on them. One of the most important is whether the development of the algal film is influenced by temperature and light. If temperature is of importance what occurs in those countries where the planting time of rice does not coincide with high temperature and what is the consequence in regard to soil æration, drainage and green-manuring or the application of large quantities of stable manure? The practices in Italy and Japan where large quantities of bulky organic manures are applied to the rice fields seem to indicate that the lower temperature does not prevent the formation of the film. If light has an important influence it may be expected that the algæ play an important part in the development of the root only so long as the crop does not yet cover the field. During that time the growth of the roots is most pronounced. May drainage be beneficial after that time?

Has soil itself anything to do with the formation of the algal film?

It is clear, that numerous other questions of practical importance may be raised, and research on rice growing may be stimulated and led into new paths.

Light and Root Development.

It is sufficiently established, that rice is an intense light loving plant. In an experiment made by Espino and Pantaleon (2) the importance was established of the intensity of sunlight in the production of dry matter in the rice plant. Great differences exist between development under full daylight conditions and under diffuse light conditions, as may be shown by the following results:—

Light Conditions.	Length of		Weight of dry matter			Shoot / Root Ratio dry matter.
	Shoot. cm.	Root. cm.	Shoot. gr.	Root. gr.	Total. gr.	
Full direct ..	67.0=100	30.4=45.4	7.38	1.87	9.25	100 : 25.3
Diffuse ..	57.3=100	22.2=39.0	2.49	0.79	3.28	100 : 31.7
Early morning .	51.8=100	12.8=25.0	2.67	0.53	3.20	100 : 20.0
Early afternoon	32.3=100	10.5=32.5	0.56	0.17	0.73	100 : 30.3

These figures relate to the average of one plant, grown during 15 days under normal conditions and under different exposures for the following 30 days, harvested when 45 days old.

It seems that there is a large difference in the influence of morning and afternoon exposure. Morning exposure and diffuse light give about equal results, except in the ratio between root and shoot development.

What causes this apparently more beneficial influence of the morning light, or rather the harmful effects of the afternoon light, is now a pertinent question.

It is common knowledge that the temperature in the tropics is higher in the afternoon than in the morning. Might it not be that the higher temperature is the principal cause of the harm, although other causes may exist ? Several investigators, as Copeland and others, have already established the fact that plants transpire more rapidly during the first hour or during the first two or three after midday than at any other time of the day. Therefore, it appears, that the harmful effects of the afternoon exposure were due to excessive transpiration. This in turn is facilitated or accelerated by the excessive heat usually experienced in the afternoon. Absence of water could not be the cause as the cultures were always sufficiently supplied.

The plants showed the following features :—

1. Full direct light. Plants healthy, with broad dark green leaves. Heavy tillers.
2. Diffuse light. Plants slender, with long narrow light green leaves. Few tillers produced.
3. Morning light. Similar to plants in culture 2.
4. Afternoon light. Plants rather weak and stunted in growth. Leaves chlorotic short, narrow and thin.

Let us now turn our attention to the harmful effects on plants of excessive transpiration. It is known that when the loss of water by transpiration through the leaves is not replaced, the leaf cells lose

turgescence. This loss of turgidity, in turn, closes the stomatal pores and may produce a drooping or flagging position of the leaves. Evidently, this was the case, as during afternoon exposure the plants appeared drowsy. From general knowledge of plant behaviour it may be supposed that the lack of growth and development of the plants during afternoon hours was due to lack of turgor of the leaf cells. Turgor is essential, at least for the initial growth of the leaves. Moreover, the closing of the stomata and the drooping position of the leaves are two conditions well known as interfering with photosynthetic activity of plants. It is, therefore, within reason to suppose that the manufacture of food slackens in the afternoon, hence, the poor growth.

From the figures reproduced above it seems that the plant under unfavourable light conditions tries to restore e quilibrium by developing more energy in root formation. The shoot-root ratio for the dry matter weight might give indications in this direction. The authors, however, state that the figures given for the weight of dry matter are not reliable and that therefore those relating to length of shoot and root are of much more value. From this it is seen, that the shoot/root ratio of plants exposed to full light conditions is highest. When we take into consideration the fact that the leaf surface is proportionally larger than that of the other parts of the plant we may assume that unfavourable light conditions upset the e quilibrium between root and shoot development, exposing the plant to the results of excessive evaporation and diminished photosynthetic activity.

Root Diseases.

In all rice cultivating countries the rice crop is often damaged by diseases of the roots, which are known under different names. They may be caused by different factors, *e.g.*, acidity, insufficient æration of the soil, reduction processes, etc.

Vander Elst studying this question in Java found a certain relation between more or less severe outbreaks of such disease and climatological factors, at least in some parts of the country, where large acreages are often damaged.

As a result of his investigations, which have not yet been published, he has already made recommendations to the agricultural extension service of the island, which has made several experiments in accordance with his advice.

Vander Elst found, that as a general rule a wet season following on a dry season which had, however, more than its normal rainfall, is certain to show a large outbreak of the disease.

The largest acreage of rice is planted at the beginning of the wet season, at which time the number of sunshine hours is very low. He found too that under such conditions root development was inferior to that under good light conditions. When, however, light conditions improved gradually outbreaks of the disease are not so severe as when the dark days of the rainy season are interrupted by a period of full bright sunshine.

Vander Elst concluded that the outbreak of this disease, at least in part, is due to a disequilibrium between the development of shoot and root.

To prevent this outbreak he therefore recommended the use of all means that may be useful to promote development of roots. He therefore recommended in the first place the use of phosphoric acid as a fertilizer, especially in the nurseries. The seedlings after transplanting show a much larger development of their root system than when grown on non-fertilized seed beds. The disease may grow worse under influence of nitrogenous fertilizers, as the disequilibrium between root and shoot becomes still more pronounced.

The influence of green manuring on the outbreak of this disease has not yet been studied, but it may be expected that a combination of phosphates and green manure will do much to check severe results.

Yields in Different Countries.

There is a large difference in œcological conditions of rice growing in the tropics and subtropics. In the latter rice growing is restricted to the summer months by reason of the temperature. But this means that rice is grown in that part of the year in which the days have the largest number of sunshine hours. In the tropics the main crop is grown in the rainy season, only a comparatively small acreage being planted in the dry season, as there is no water available at that time to plant a larger acreage. The result is that in the main growing season only a few hours of sunlight are available per day, the day being shorter than in the subtropical summer and heavy clouds overhanging the sky often for many days (1).

This factor has a large influence on the production of dry matter by the rice-plant, but a still larger influence on the development of its roots. And for this reason the plant cannot make use of manures in the same way as is the case in subtropical countries.

Spain, Italy and California are especially favoured in this respect, Japan having its rainy season also in summer time. It is, however, very difficult to make comparisons between these countries for the reason

that in the first three, rice being mainly a commercial crop, only the best adapted fields are used for rice, whereas in the oriental countries every field that can be irrigated is used.

Comparing, therefore, Japan only with other oriental countries we find for the yield per ha. for Japan 34.1 centner, for Siam 17.3, the Philippines 12.2, Indo-China 11.2 and Java 16.

We may expect that in Japan manuring plays an important part to get this average, but the numerous experimental fields in Java give by a liberal use of fertilizer yields that do not exceed the average yield of Japan. The highest yields there must be still very much larger.

It is at the same time interesting to see that the average yield of Korea is not more than 16.7 centner per ha. But it is known that the sky of Korea in summer-time is very much more cloudy than in Japan, often for many days at a stretch.

This question is of great importance, for in tropical countries, it is often asked why even in the experimental fields, the high yields of Japan are not reached. It seems questionable if it is possible to reach those figures.—*International Review of Agriculture*, Year XXII, No. 5.

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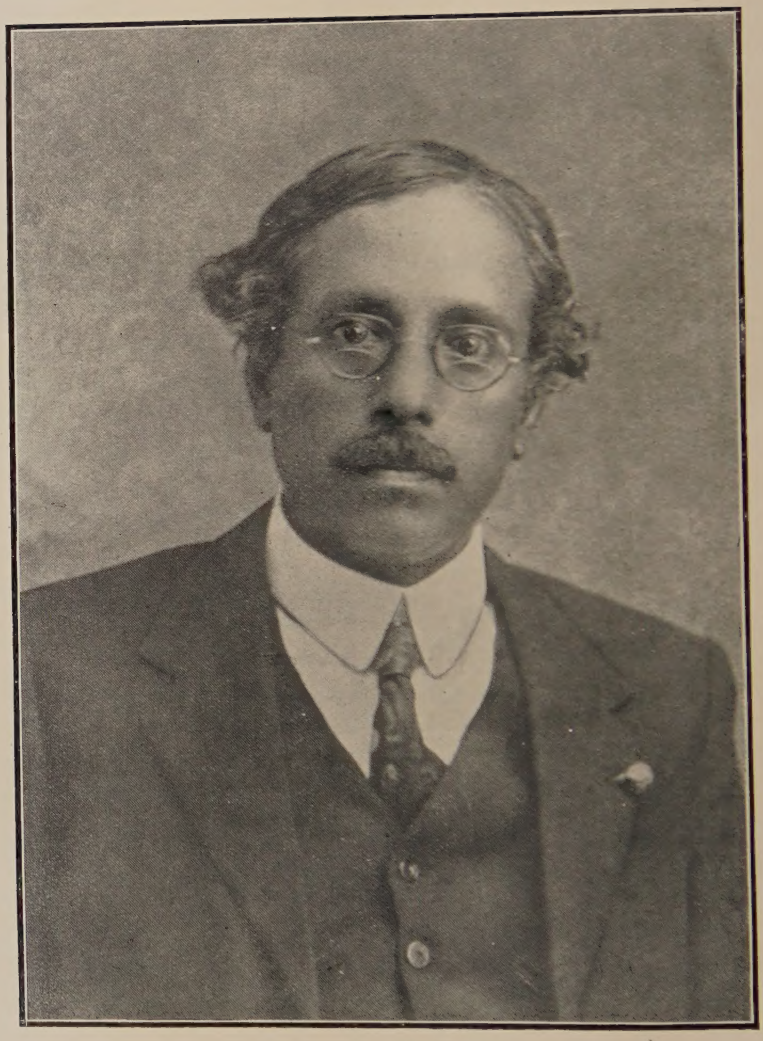

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